A 5: Attosecond physics

Time: Monday 14:00–15:45 Location: B 305

Prize Talk A 5.1 Mon 14:00 B 305

Taming light waves: Attosecond triggering and clocking of electronic processes — •Eleftherios Goulielmakis — Max Planck Institute for Quantum Optics, Garching, Germany — Laureate of the Gustav-Hertz-Prize

Real-time control of electrons in the microcosm calls for electromagnetic forces confinable and tunable over sub-femtosecond time intervals. We will discuss how recent progress in lightwave technologies [1-5] has enabled important steps towards this essential milestone in science and technology. With novel types of light synthesizers that manipulate ultrawideband coherent light sources, spanning the visible and flanking spectral ranges, it is now possible to sculpt [4],[5] and trace [1] the waveform of light with subcyclic precision opening up the root to attosecond photonics.

To explore the potential of the new tools for advancing microscopic manipulation of matter, we have used synthesized light transients to demonstrate basic elements of sub-femtosecond control of electrons such as attosecond triggering and clocking of electron dynamics in the valence shell of atoms [6],[7] and their real-time tracing [6].

[1] E. Goulielmakis et al., Science 305, 1267 (2004).
[2] E. Goulielmakis et al., Science 320, 1614 (2008).
[3] E. Goulielmakis et al., Science 317, 769 (2007).
[4] A. Wirth et al., Science 334,195 (2011).
[5] M. Th. Hassan et al., Rev. Sci. Instrum. 83,111301 (2012).
[6] E. Goulielmakis et al., Nature 466, 739 (2010).
[7] M. Th. Hassan et al., in preparation (2013).

A 5.2 Mon 14:30 B 305

Interferometric Laser Control of Attosecond Pulse Generation — •Philipp Raith, Christian Ott, Andreas Kaldun, Kristina Meyer, Christopher Anderson, Martin Laux, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg , Germany

Tailored attosecond pulses would allow to measure and control electron quantum dynamics in atoms and molecules on their natural time scale. Here, we control the generation of attosecond pulses and pulse trains, produced by high-harmonic generation, by two control variables: The carrier-envelope phase (CEP) of the driving laser field and a time delay between two variable sections of the laser spectrum [1]. We experimentally and numerically demonstrate that this multidimensional control scheme allows to independently set several properties of the produced attosecond pulses or pulse trains such as their relative phase and intensity ratio. Moreover, we show that the controlled interference of two temporally-spaced attosecond pulse trains leads to the generation of fractional high-harmonic combs [2]. Furthermore, we give experimental and computational evidence that an interference effect drastically magnifies the influence of subcycle time delays between spectral channels on the effective carrier-envelope phase of the synthesized laser field by rapidly moving the envelope temporally across a quasi-stationary carrier wave. This finding has important consequences for the CEP stabilization of few-cycle synthesized light fields.

[1] P. Raith et al., Opt. Lett. 36, 283-285 (2011).
[2] P. Raith et al., Appl. Phys. Lett. 100, 121104 (2012).

A 5.3 Mon 14:45 B 305

On imaging the instantaneous electron density with ultrafast x-rays: Is it possible? — •Jan Malte Slowik[1,2], Gopal Dixit[1], and Robin Santra[1,2] — [1]Center for Free-Electron Laser Science, DESY, Hamburg, Germany — [2]Department of Physics, University of Hamburg, Hamburg, Germany

Tracing the dynamical evolution of the electron density has enormous relevance to understanding ultrafast phenomena occurring for example in chemical and biological processes. Scattering of ultrashort x-ray pulses from an electronic wavepacket would appear to be an obvious approach to image the electronic motion in real-time and real-space. However, the scattering pattern in the far-field regime does not encode the instantaneous electron density of the wavepacket, but probes spatio-temporal density-density correlations. Here, we propose a possible way to image the instantaneous electron density of the wavepacket via ultrafast x-ray phase contrast imaging. Moreover, we show that inelastic scattering processes, which plague ultrafast scattering in the far-field regime, do not contribute in ultrafast x-ray phase contrast imaging as a consequence of an interference effect. Our general findings will be illustrated by means of a wavepacket that lies in the time and energy range of the dynamics of valence electrons in complex molecular and biological systems. This approach offers a potential to image not only instantaneous snapshots of electron dynamics in non-stationary quantum systems, but also the Laplacian of these snapshots which provides information about the complex bonding and topology of the charge distributions in the systems.

A 5.4 Mon 15:00 B 305

Kinematically complete photoionization studies with online monitoring of XUV attosecond pulse properties — •Michael Schönwald[1], Philipp Coerlin[1], Andreas Fischer[1], Alexander Sperl[1], Arne Senftleben[1], Thomas Pfeifer[1], Joachim Ullrich[1,2], and Robert Moshammer[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Deutschland — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Deutschland

We are producing attosecond pulses (AP) via high harmonic generation (HHG) in a small gas cell filled with rare gases in order to do pump-probe experiments in a reaction microscope (ReMi). A self-phase modulation hollow fiber filled with Neon in combination with a chirped mirror compressor is used to broaden the spectrum and to shorten the infrared (IR) laser pulses from 30 fs to less than 10 fs for experiments with single AP. We perform kinematically complete experiments using a Reaction Microscope (ReMi) which require long-term stability of the incoming radiation. To monitor the HHG spectra and to be able to estimate the pulse durations of the AP, we build a new extended ultraviolet (XUV) spectrometer which uses the light transmitted through the interaction region of the ReMi. A spherical mirror is then used to focus the high harmonics onto a MCP detector. Before hitting the detector the XUV radiation is spectrally resolved by a reflection grating. We will show first experiments in which we combine the information given by the spectrometer and by an optical autocorrelation of the IR laser field. With the online monitoring we are able to perform and to compare experiments with different pulse durations.

A 5.5 Mon 15:15 B 305

Prediction of attosecond light pulses in the VUV range in a high-harmonic generation regime — •Jost Henkel[1,2], Tobias Witting[2], Davide Fabris[2], Manfred Lein[1], Peter L. Knight[2], John W. G. Tisch[2], and Jonathan P. Marangos[2] — [1]Institut für Theoretische Physik and Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover Appelstraße 2, 30167 Hannover, Germany — [2]Blackett Laboratory, Imperial College London, Prince Consort Road, South Kensington, London SW7 2AZ, UK

Attosecond (as) pump-probe experiments are one of the ultimate goals for the investigation of electron and hole dynamics in atoms and molecules. For an efficient transient population of specific excited states, strong short light pulses with a narrow frequency spectrum are needed. To overcome limitations of current XUV sources, we propose to select high-harmonic frequencies in the VUV range with an indium filter. Its transmission window is centered at 15 eV and has a bandwidth of 3.7 eV, yielding a Fourier limit of 700 as. We confirm this by calculating high-order harmonic spectra from the solution of the time-dependent Schrödinger equation (TDSE). For a model neon atom we compare linearly polarised laser pulses to the polarisation gating method with elliptical pulses. Such below threshold harmonics have low sensitivity to the generating field's ellipticity, leading to elliptically polarized attosecond pulses. The problematic lack of spontaneous decay in the TDSE, which causes strong below-threshold emission peaks, can be circumvented by accounting for macroscopic intensity averaging.

A 5.6 Mon 15:30 B 305

Phase-Matching Studies of High-Order Harmonic Generation from Water Droplets — •Heiko G. Kurz[1,2], Daniel S. Steingrube[1,2], Martin Kretschmar[1,2], Tamas Nagy[1], Detlev Ristau[1,2,3], Manfred Lein[2,4], Uwe Morgner[1,2,3], and Milutin Kovacev[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik, Welfengarten 1, Hannover — [2]QUEST, Centre for Quantum Engineering and Space-Time Research, Welfengarten 1, Hannover —

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We report on systematic investigations of frequency up-conversion into the extreme ultraviolet spectral domain. Two intense femtosecond laser pulses interact with a micrometer-sized liquid water droplet under vacuum conditions. Therein, high-order harmonic radiation of the fundamental frequency is generated (HHG) in a target with controllable density, reaching from liquid state to gaseous, and even the plasma state. We investigate how the density and the dynamics of a complex target influence the HHG yield. Harmonic radiation up to the 29th harmonic order is generated and a strong dependency of the harmonic yield on the spatio-temporal behaviour of the target is found. We detect only a small amount of incoherent radiation. The spatio-temporal dynamics of the droplet, such as the expansion of the droplet and plasma formation during interaction with intense laser pulses are controlled by variation of the intensity of the pump pulse and its influence onto HHG is observed.